Globalization and Granger Causality in International Stock Markets

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Abstract – **This paper analyzes the process of stock market globalization on the basis of cointegration and Granger causality tests. Granger causality is based on regression modelling and typically captures current and past causal relationships in the data. The dataset used in our empirical analysis was drawn from DataStream and comprises the natural logarithm of relative stock market indexes since 1973 for the G7 countries. The main results point to the conclusion that significant causal effects occur in this context with well-defined causal directions. There is also evidence that stock markets are closely related in the long-run over the 36 years analyzed and, in this sense, one may say that they are globalized. As expected, there is evidence that the US stock market dominates in general over the remaining markets.**

Keywords - *Cointegration, Globalization, Granger Causality, Stock Market.*

1. Introduction

Recent debates on economic globalization have triggered a substantial amount of research papers that try to determine its causes and explain the consequences of this phenomenon in terms of market performance and their ability to adjust globally to economic boosts and crisis. This has been particularly relevant in the case of financial markets and even more so in the case of stock markets. Indeed, the process of globalization of international stock markets has been deeply studied both by economists and other researchers interested in this subject such as, for instance, physicists and, invariably, they conclude that stock markets are highly "globalized" [Kasa (1992), Arshanapalli and Doukas (1993), Chung and Liu (1994), Masih and Masih (1997, 2002), Zhou and Sornette (2003), Tavares (2009)]. However, many of these studies lack a theoretical background that supports their view of what is globalization and how it can be measured, or they do not simply address the issue of the causality direction, which makes all the difference for policy purposes [Hamao et al. (1990), Drożdż et al. (2001)].

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Globalization, in its literal sense, is the process of transformation of local or regional phenomena into global ones and can be described as a process by which the world population is gradually more integrated into one sole society. That is, globalization implies uniformity in terms of tastes, behaviors, prices, goods accessibility, and much more. It is a process of interaction among the economic and social agents (people, firms, etc) driven by international trade and investment and aided by information technology that reduced significantly the geographical distance barriers and communication difficulties between people living in different parts of the world.

One important aspect of economic globalization is market integration. In the sense of Stigler (1969) and Sutton (1991), a market is "the area within which the price of an asset tends to uniformity after allowing for different transportation costs, differences in quality, marketing, etc". On the other hand, market integration refers to proportionality of price movements over time for an asset or group of assets. The economic variable price is, therefore, a key element in the process of market globalization and provides a suitable framework for testing market integration by looking at the price relationship of assets over time. Strictly speaking we should look at proportionality of price movements over time for a given asset sold in geographically separated markets in order to show whether these markets are integrated or not. This is what we may call strong market integration but, in many cases, market integration only occurs in a weak or imperfect way. If this is so, one can expect nonlinearities and other types of price distortions to be present in the process of price transmission and a test of weak market integration can be performed on the basis of causality between prices, independently of whether they are proportional or not over time. If changes are proportional over time then the markets are said to be strongly integrated.

This definition of market integration can be mathematically expressed as a dynamic model where the long-run and the short-run effects can be clearly separated, known as the error correction mechanism.

This model is quite flexible and allows for different impacts of price and returns (or log price changes) movements across markets. For example, a change in the US market, usually considered as the dominant market, may be transmitted in quite different manners to the remaining markets, in which case it is difficult to conclude that markets tend to uniformity. This is not compatible with strong market integration but fits very well in the notion of weak market integration. Indeed, the process of market globalization is complex and the nonlinear transmission of price movements must be properly accommodated within the context of stock market globalization [Menezes et al. (2004, 2006)].

One advantage of the error correction model is that it allows for historical prices and returns to affect simultaneously the behavior of current stock market prices over time. Using historical prices and returns in this context is preferable to using just stock returns since the former retain both the long-run and the short-run information contained in the data, while the latter only capture the short-run information. This statement is valid under the assumption that prices are cointegrated, an issue that was extensively analyzed elsewhere [Engel and Granger (1987), Eun and Shim (1989)]. On this basis, one can construct statistical tests to verify whether the past (and present) information contained in prices and returns of, say, market A, help to explain the behavior of prices and returns of market B. This is what we mean by Granger causality and, under this hypothesis, one can say that knowing the behavior of prices in market A allows one to explain or even predict the behavior of prices in market B. A concise description of this method is presented in the next Section. Following, we present the data set used in our empirical analysis and the main results that were obtained. Finally, we present the main conclusions of the paper.

2. Methodological Issues

As noted above, one way to analyze the extent of market integration, and thus globalization, is by using Granger causality tests [Granger (1969)] which can be defined as follows: X_{2t} Granger causes X_{1t} if, *ceteris paribus*, the past values of *X2t* help to improve the current forecast of *X1t*, that is:

$$MSE\left(\hat{X}_{1t} \mid I_{t-1}\right) < MSE\left(\hat{X}_{1t} \mid I_{t-1} \setminus IX_{2,t-1}\right), \quad (1)$$

where *MSE* is the mean squared error, I_{t-1} represents the set of all past and present information existing at moment $t-1$, $IX_{2,t-1}$ represents the set of all past and present information existing on X_2 at moment $t-1$, *i.e.*, $IX_{2,t-1} = \{X_{21}, X_{22}, \ldots, X_{2t-1}\}$, X_{1t} is the value of X_1 at the moment t ($X_{1t} \subset I_t$) and $\hat{X}_{1t}$ is a non-biased predictor of X_{1t}. On the other hand, X_{2t} instantaneously causes X_{1t} in the sense of Granger if, *ceteris paribus*, the past and present values of X_{2t} help to improve the prediction of the current value of X_{1t}, that is:

$$MSE\left(\hat{X}_{1t} \mid I_t \setminus X_{1t}\right) < MSE\left(\hat{X}_{1t} \mid I_t \setminus IX_{2,t}, X_{1t}\right) \quad (2)$$

Given these definitions, how can we empirically implement these tests? To see this, consider the following ADL(p, q) price relationship:

$$X_{1t} = \theta + \sum_{k=1}^{p} \rho_k X_{1,t-k} + \sum_{j=0}^{q} \beta_j X_{2,t-j} + v_t, \quad (3)$$

where X_{it} ($i = 1, 2$) denotes the relative prices (in natural logs) of asset i at time t, ρ_k captures the extent of autocorrelation in X_{1t}, β_j measures the relationship between prices (in levels and lags) and v_t is a white noise perturbation. One can say that X_{2t} causes X_{1t} if the null hypothesis that all parameters β_j are simultaneously zero is rejected. The relationship can be bidirectional and, in this case, we say that there is a feedback relationship. If there is just one unidirectional causal relationship, then one of the markets can effectively influence the other market prices, but the reverse is not true. If the null hypothesis is not rejected in both cases, then there is no causal relationship between the underlying prices and one can say that they do not belong to the same market space. In practice, however, the Granger causality test performed in statistical software postulates as the null hypothesis that "X_{2t} does not Granger cause X_{1t}".

In multivariate cointegrated systems the Granger causality test can be performed on the basis of a VEC model of the type [Sargan (1964)]:

$$\Delta \mathbf{X}_t = \boldsymbol{\alpha\beta}' \mathbf{X}_{t-1} + \sum_{k=1}^{p-1} \boldsymbol{\Gamma}_k \Delta \mathbf{X}_{t-k} + \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t, \quad (4)$$

where $\mathbf{X}_{t-1}$ is an i-dimensional vector of cointegrated lagged endogenous variables representing, for instance, natural logarithms of relative asset prices (*e.g.*, stock indexes) at time $t-1$. $\Delta\mathbf{X}_t$ and $\Delta\mathbf{X}_{t-k}$ denote returns at time t and $t-k$, respectively, where Δ is the operator of first difference. $\boldsymbol{\Gamma}_k$ denotes $p-1$ i-order matrices of short-run information parameters where each of them is associated with an i-dimensional vector of lagged returns up to order $p-1$. $\boldsymbol{\alpha\beta}'$ is an i-order matrix of long-run information parameters, where $\boldsymbol{\alpha}$ represents the adjustment speed to equilibrium and $\boldsymbol{\beta}$ contains the long-run or equilibrium coefficients. $\boldsymbol{\mu}$ is an i-dimensional vector of constants and $\boldsymbol{\varepsilon}_t$ denotes an i-dimensional vector of residuals where $\boldsymbol{\varepsilon}_t \sim \text{iid}(\mathbf{0}, \boldsymbol{\Omega})$. Note that the residuals $\boldsymbol{\varepsilon}_t$ are not serially correlated since the dynamic process linking the data is explicitly specified in the model, although they may be contemporaneously correlated.

The VEC model represented in (4) can be interpreted as a relationship between prices and returns in a given market. What it says is that the current returns are a linear function of previous returns and historical prices. Such historical prices form a long-run equilibrium relationship, where the involved variables co-move over time independently of the existence of stochastic trends in each of them, so that their difference is stable. The long-run residuals measure the distance of the system to equilibrium at each moment t, which may be due to the impossibility of the economic agents to adjust instantaneously to new information or to the short-run dynamics also present in the data. There is, therefore, a whole complex adjustment process involving short-run and long-run dynamics when the variables are cointegrated.

Simple manipulation of the VEC model leads to a reparameterized version where the vector μ is multiplied by the estimated long-run residuals and the matrices $\mathbf{A}_i$ ($i = 1, \ldots, m$) contain the coefficients of the lagged returns for each variable separately. For a two cointegrated variable system and p lags[1], and noting that $\hat{u}_{t-1} = \hat{\boldsymbol{\beta}}'\mathbf{X}_{t-1}$, one has:

$$\Delta \mathbf{X}_t = \mathbf{A}_1 \Delta \mathbf{X}_{1,t-j} + \mathbf{A}_2 \Delta \mathbf{X}_{2,t-j} + \boldsymbol{\mu} \hat{u}_{t-1} + \boldsymbol{\varepsilon}_t, \quad (5)$$

where $\Delta\mathbf{X}_t$ represents returns or log price changes at time t and $\Delta\mathbf{X}_{i,t-j}$ ($i = 1, 2;\ j = 1, \ldots, p-1$) denotes lagged returns up to $p-1$ of the i^{th} variable. $\mathbf{A}_1$ and $\mathbf{A}_2$ are $[2\times(p-1)]$ matrices. $\boldsymbol{\mu}$ and $\boldsymbol{\varepsilon}_t$ are (2×1) vectors and $\hat{u}_{t-1}$ denotes the long-run residuals, where $u_t \sim \text{I}(0)$. A Granger causality test can be carried out on the basis of the null hypothesis: $\delta_{i1} = \ldots = \delta_{i,p-1} = \mu_i = 0$, where the δ_i coefficients correspond to the i^{th} row of $\mathbf{A}_2$. The test then compares the mean squared error under the null and under the alternative hypotheses.

[1] Notice, however, that the number of lags can be different for each variable.

3. Data and Results

The dataset used in our empirical analysis consists of seven daily stock price series representing the G7 countries: US, Canada, Japan, UK, Germany, France and Italy. The data are the relative price indexes for these markets, where the base 100 was set at January, 1st 1973. The series were collected in the Datastream database and cover the period from January, 1st 1973 to January, 21st 2009, totalizing 9408 daily observations (five days per week). Figure 1 shows a graphic of the seven series in relative prices (panel a) and in the natural logarithms of relative prices (panel b).

It is remarkable how similar the time-path pattern looks for these seven stock market indexes with market boosts and crises apparently synchronized for all the countries (panel a). Data dispersion increases substantially along time, especially after the oil crisis of the early eighties and, further on, since the end of the 20th century. Price volatility over the period was substantially higher for Italy, France and the UK than for Canada, the US, Germany and Japan. In addition, all price histograms that are shown in Figure 1a exhibit a right-hand side long tail. The series in logs (panel b) lessen volatility in the data, as expected, and the log price histograms appear flattened. However, data dispersion does still increase over time. Some descriptive statistics of these series (in natural logarithms) are presented in Table 1.

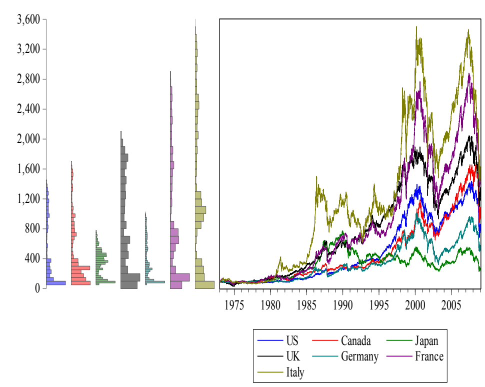
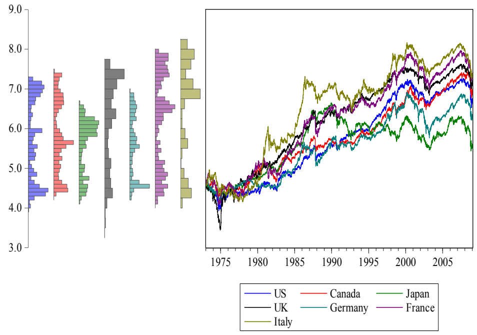


Figure 1a. Relative price indexes for the G7 countries



Source: Datastream. Base 100: January, 1st 1973. 9408 data points.

Figure 1b. Natural logarithms of relative price indexes for the G7 countries

Table 1. Descriptive statistics of the natural logarithms of relative prices

	US	Canada	Japan	UK	Germany	France	Italy
Mean	5.706510	5.779643	5.604483	6.179921	5.545114	6.226555	6.516560
Median	5.650874	5.662144	5.861683	6.434844	5.584004	6.474808	6.917948
Maximum	7.267135	7.433217	6.645377	7.621871	6.917379	7.964677	8.161164
Minimum	3.932218	4.297829	4.120337	3.446577	4.205439	4.070223	4.153556
Std. Deviation	1.035847	0.895167	0.668453	1.113543	0.789030	1.150704	1.238936
Skewness	0.025493	0.130726	-0.634781	-0.500333	0.009600	-0.228873	-0.592996
Kurtosis	1.508327	1.842078	2.038909	1.929123	1.653605	1.686334	1.977588
Jarque-Bera	873.2535	552.3834	993.9092	842.0589	710.7536	758.6182	961.1455
p-value	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	53686.84	54374.88	52726.97	58140.69	52168.43	58579.43	61307.80
Sum Sq. Dev.	10093.50	7538.058	4203.324	11664.46	5856.504	12455.99	14439.40
N	9408	9408	9408	9408	9408	9408	9408

Notice that all series are flatter than the Gaussian distribution and slightly skewed, therefore the J-B test statistic rejects the null hypothesis of normality for all of them. This is typical of stock market price series in the same manner as leptokurtosis and fat tails are typically observed in returns data. From this point onwards the analysis will only consider the natural logarithms data, that is, stock prices actually refer to the natural logarithms of the relative price indexes and stock returns or price changes denote the difference between log relative prices at two adjacent dates.

Before proceeding to the analysis of market integration one should look at the (none) stationary nature of the G7 series. Unit root and stationarity tests in levels and in first differences for all the series are shown in Table 2.

Table 2. Unit root and stationarity tests in levels and in first differences

Variable	ADF[a, c, d]	KPSS[b, c, d]
US[f]	-1.709328	0.960241 **
Canada[e]	-2.806501	0.468607 **
Japan[f]	-0.269712	2.549435 **
UK[g]	-0.736909	2.320246 **
Germany[e]	-1.722877	0.568883 **
France[e]	-1.050611	1.038102 **
Italy[g]	-0.500341	1.661498 **
ΔUS	-70.39091 **	0.244395
ΔCanada	-88.91458 **	0.075838
ΔJapan	-69.26301 **	0.126957
ΔUK	-45.20940 **	0.220531
ΔGermany	-92.36380 **	0.130575
ΔFrance	-89.32861 **	0.186063
ΔItaly	-44.66293 **	0.302849

Notes: [a] MacKinnon (1996) critical values: -3.43 (1%) and -2.86 (5%) for constant and -3.96 (1%) and -3.41 (5%) for constant and linear trend. [b] Kwiatkowski-Phillips-Schmidt-Shin (1992; table 1) critical values: 0.739 (1%) and 0.463 (5%) for constant and 0.216 (1%) and 0.146 (5%) for constant and linear trend. [c] exogenous terms in levels: constant and linear trend. [d] exogenous terms in 1st differences: constant (except for Japan in the KPSS test which is constant and linear trend). [e] 1 *lag* in levels for ADF. [f] 2 *lags* in levels for ADF. [g] 4 *lags* in levels for ADF. ** significant at 1%.

The ADF and KPSS tests are designed to capture weak stationarity with opposite null hypotheses. In the former case the null hypothesis of nonstationarity of the variables in levels is not rejected but it is rejected at 1% for the variables in first differences. In the latter case the null hypothesis of stationarity in levels is rejected at 1% but it is not rejected in first differences. The results are, therefore, consistent in both cases and lead to the conclusion that the price series under analysis are, in fact, integrated of first order. The number of lags selected in each test was set on the basis of the SBC information criterion [Schwarz (1978)]. One can thus conclude that the stock price series under analysis are nonstationary while returns are stationary. The next step refers to the cointegration tests in order to verify whether non-spurious causal relationships can be established among the variables being studied. The Johansen test statistics are presented in Table 3.

Table 3. Johansen cointegration tests

Rank	Eigenvalue	Trace Statistic[a]	Max-Eigenvalue Statistic[a]
$r = 0$	0.005329	153.0157 **	50.25020 *
$r \le 1$	0.004587	102.7655	43.24244
$r \le 2$	0.002368	59.52310	22.29762
$r \le 3$	0.001934	37.22548	18.20505
$r \le 4$	0.001430	19.02043	13.45522
$r \le 5$	0.000539	5.565207	5.073572
$r \le 6$	5.23E-05	0.491635	0.491635

Notes: [a] MacKinnon-Haug-Michelis (1999) *p*-values. Exogenous terms in CE: constant and quadratic deterministic trend. 2 *lags* in the endogenous variables. 9405 observations. ** significant at 1%. * significant at 5%.

The results indicate that there is one cointegrating vector since the null hypothesis that $r = 0$ is rejected at 1% in the trace test and at 5% in the maximum eigenvalue test but the null $r \le 1$ is not rejected at standard levels. This means that the seven stock markets under analysis belong to the same market space and there is a long-run equilibrium relationship linking price data along with the dynamic short-run terms denoting market returns. Altogether, these results outline the starting point for analyzing market integration on the basis of Granger causality. The Granger causality F-statistics are presented in Tables 4 to 6.

Table 4. Granger Causality F-statistics in levels

Variable	US	Canada	Japan	UK	Germany	France	Italy
US	-	142.898 **	716.963 **	475.981 **	390.273 **	470.843 **	156.006 **
Canada	36.0065 **	-	361.477 **	113.420 **	73.5093 **	117.433 **	46.4521 **
Japan	14.3828 **	4.86702 **	-	27.3334 **	21.9847 **	24.1686 **	7.23094 **
UK	8.91317 **	3.99597 *	233.251 **	-	7.33226 **	6.02136 **	3.54475 *
Germany	6.03121 **	2.29723	284.715 **	1.13299	-	2.17821	0.32732
France	9.72877 **	1.51540	259.915 **	6.42979 **	1.54816	-	1.21910
Italy	1.93860	1.01208	107.911 **	0.61978	1.42051	7.52491 **	-

Notes: H_0: X_{it} does not Granger cause X_{jt} ($i \neq j$). 2 *lags*. 9406 observations in each series. ** significant at 1%. * significant at 5%.

Table 4 presents the Granger causality tests for the variables in levels, that is, stock prices. Recall that the test is interpreted as follows: X2t Granger causes X1t if, ceteris paribus, the past values of X2t help to improve the current forecast of X1t, where X2t represents the variables in the first column and X1t represents the variables in the first row. One can say, therefore, that for the significant causal relationships the historical prices of the former market affect the current price of the latter, forming a dynamical long-run relationship in the global economy. As we can see, about 74% of the coefficients are statistically significant, which means that there is substantial long-run causal effects among these markets, of which many of them are feedback relationships. However, we found no causal relationship in any direction for the pairs Germany-France and Germany- Italy.

Another important result is that, in the long-run, the US causes more than is caused by other markets. To see this, note that the F-statistics of the former (1st row) are substantially larger than the F-statistics of the latter (1st column). This is consistent with the idea that the US stock market, to a greater extent, 'exports' more than ‘imports’ boosts and crises, being therefore the engine of the global financial world. For example, a crisis with origin in the US can spread in a broader way to other markets (as it seems in the current crisis) than a crisis with origin in Japan or even any European country. Canada shows an overall picture very similar to the US, that is, in general it causes more other markets than is caused by them, except in what refers to the US. Canada, however, appears to be caused only by the US, Japan and, to a lesser extent, the UK. Conversely, Japan is the most endogenous of the G7 markets. The European countries do not show an overall systematic pattern of causality, though the UK appears to emerge like an attractor in the EU context (but not with France) and follows the North-American markets. This is surprising insofar we would expect Germany to be the leading European stock market, given its role as the head of the European Union economy, albeit one should recognize the very important role of the London Stock Exchange in the global financial world.

Table 5 presents the Granger causality tests for the variables in first differences, that is, returns. The results show how much historical returns of one market affect the current returns of another market, making up therefore a dynamical short-run relationship in the system. Here, some 71% of the coefficients are statistically significant and we found no causal relationship in any direction only for the pair Germany-Italy (as in the long-run tests). Otherwise, the overall picture is the same as for the results in levels.

In the short-run, the North-American markets cause more other markets than are caused by them and the US leads the Canadian market. The opposite occurs for Japan as in the long-run. Again, the UK emerges as an attractor in the European Union context (except with France) but follows the North-American markets. It seems, therefore, that market causality among the G7 countries is present both in the long-run and in the short-run, affecting co-movement prices and returns.

Table 5. Granger Causality *F*-statistics in first differences

Variable	ΔUS	ΔCanada	ΔJapan	ΔUK	ΔGermany	ΔFrance	ΔItaly
ΔUS	-	138.970 **	708.196 **	491.025 **	387.364 **	476.872 **	154.376 **
ΔCanada	30.8130 **	-	369.375 **	123.680 **	74.2408 **	128.220 **	47.4845 **
ΔJapan	7.60523 **	3.61023 *	-	25.5639 **	17.2502 **	19.6704 **	5.39895 **
ΔUK	2.27861	3.71751 *	238.670 **	-	3.34280 *	0.07240	3.77099 *
ΔGermany	3.37056 *	2.36538	277.860 **	0.74040	-	3.50272 *	0.25046
ΔFrance	4.97310 **	0.80771	263.282 **	6.15885 **	0.91485	-	1.14968
ΔItaly	2.13516	2.54945	108.852 **	1.06984	2.05813	7.76945 **	-

Notes: H_0: X_{it} does not Granger cause X_{jt} ($i \neq j$). 2 *lags*. 9405 observations in each series. ** significant at 1%. * significant at 5%.

Finally, Table 6 presents the Granger causality results for the variables in first differences but where X2t now represents the first lag of the underlying variable. The results can be interpreted in terms of a delayed effect of returns of one market onto the current returns of another market. It should be noted the size of the F-statistics in this Table, where all the coefficients are significant at much less than 1%. The overall picture is, however, the same as before. Historical delayed returns worldwide have a significant impact on current returns for all the cases. In our context, historical delayed returns were only computed for one lag while one can believe that smoother but significant effects may also occur for two or more lags, though one lag computations will suffice for our purposes.

Table 6. Granger Causality *F*-statistics in first differences (lagged effects)

Variable	ΔUS	ΔCanada	ΔJapan	ΔUK	ΔGermany	ΔFrance	ΔItaly
ΔUS(*t*−1)	-	4403.8 **	770.35 **	1237.9 **	1196.1 **	1181.1 **	420.91 **
ΔCanada(*t*−1)	4198.8 **	-	525.63 **	961.60 **	761.95 **	851.67 **	314.22 **
ΔJapan(*t*−1)	63.808 **	160.49 **	-	327.92 **	321.30 **	307.39 **	154.97 **
ΔUK(*t*−1)	690.58 **	830.07 **	542.91 **	-	1482.9 **	2122.2 **	755.22 **
ΔGermany(*t*−1)	751.19 **	678.05 **	599.03 **	1480.6 **	-	2593.0 **	1006.0 **
ΔFrance(*t*−1)	652.79 **	715.79 **	555.44 **	2131.1 **	2589.7 **	-	1048.5 **
ΔItaly(*t*−1)	260.01 **	267.33 **	260.49 **	754.62 **	1001.9 **	1054.0 **	-

Notes: H_0: X_{it} does not Granger cause X_{jt} ($i \neq j$). 2 *lags*. 9404 observations in each series. ** significant at 1%.

Globally, the Granger causality results point to the existence of a single global stock market leaded by the US. The UK emerges as a regional leader within the European context. Japan, however, does not emerge as a leading market within the G7 countries but this is probably due to the long-lasting economic crisis that Japan has been facing. The great surprise (or perhaps not) is the dominant position of Canada relative to many other G7 countries. Canada may benefit from its proximity to the US where, surely, intense economic relationships, some similar economic policies and firm's relationships turn up North-America as a unified financial block. The results are, overall, compatible with the definition of weak market integration introduced in this paper although do not capture nonlinearities in the data. One can thus conclude that weak market integration occurs within the G7 over the period analyzed.

4. Conclusions

This paper analyzes stock market integration in the context of the global economy for the G7 countries. The theoretical background is rooted on a new concept of weak market integration which is defined as the causality that occurs in price transmission independently of whether this process is proportional or not over time. This allows for nonlinearities and other types of price distortions to be present in the overall process. Under proportionality of price transmission we say that strong market integration occurs. The empirical modelling of market integration based on price data is complicated by the nonstationary nature of these data sets. In order to acknowledge the nonstationarity problem, tests for unit roots and cointegration were performed prior to the empirical analysis of market integration based on Granger causality and mutual information tests. The unit root results are consistent with nonsationarity, and cointegration is present for the G7 stock markets over the 36-year period under analysis. It is therefore consistent to say that these markets belong to the same space, i.e., they actually form a single global stock market with one long-run or equilibrium relationship linking the data.

The cointegration results obtained assure that we are not facing spurious relationships between the seven markets under analysis. Thus, market integration can be tested using Granger causality. The results are consistent with the notion of pairwise weak market integration, since there are substantial causal effects, possibly linear and/or nonlinear, between pairs of variables. These effects occur both for prices and returns. They are also present for lagged returns relationships. Future work will look into the nature of the nonlinear relationships between stock markets, in particular with respect to the distinction between stochastic and deterministic effects and provide a robust basis to make prediction in the context of market integration.

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